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INFILTRATION AND RUNOFF STUDIES IN
REGION 6

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Report to Dr. W. D. Lowdermilk
October, 1937

BY

Claude L. Fly,
Associate Soil Scientist

UNITED STATES
DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Amarillo, Texas
October 12, 1937

Dr. W. C. Lowdermilk, Chief
Soil Conservation Research
Soil Conservation Service
Washington, D. C.

Dear Dr. Lowdermilk:

Your memorandum of September 27 regarding infiltration and runoff studies in Region 6 has been referred to this section.

Up to date two lines of investigations have developed in the Region. At Colorado Springs members of the State Coordinator's staff in cooperation with the local projects constructed a "rainmaker" with which they made several hundred tests on project and camp areas. A brief field report of this work was made in July, 1937. It is quite possible you have a copy of this report, and I feel sure Mr. R. E. Horton has a copy.

Tests were run with this apparatus at Clayton, New Mexico, in March, 1937, and since that time the Project Manager has decided to construct another one. I have been helping him and we are trying to include all the improvements suggested in the Colorado Springs paper, together with several of our own ideas. These are discussed in the attached report.

Since the summer of 1936, I have made infiltration studies at times when other duties would allow. Projects on which tests have been made to date include Guymon, Oklahoma, Clayton, New Mexico, Clovis, New Mexico, and Cheyenne Wells, Colorado. The original apparatus used was designed after Carpenter's at Albuquerque, New Mexico. Since that time numerous changes have been made in both apparatus and procedure. Included are designs of apparatus used for testing water intake, together with two graphs showing some of the results obtained.

All of the methods and apparatus thus far developed have been primarily intended to furnish practical information for selection, construction design and spacing of mechanical structures needed in our coordinated program of soil and water conservation.

There is a dire need for standardization of apparatus and methods, together with provisions for extending the usefulness of this and other field testing services to all phases of the soil and water conservation program.

Very truly yours,

Claude L. Fly

Claude L. Fly
Assoc. Soil Scientist

CLF:ecb

Enclosures

INFILTRATION AND RUNOFF STUDIES IN REGION 6

Brief Report to Dr. W.D.Lowdermilk
October, 1937

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A. "Rainmaker" or Runoff Studies.

1. Description of Apparatus.

The equipment, which is readily mobile, is designed to throw a uniform spray over an inclosure 21 feet in length and 6 feet in width or a total area of 126 square feet. Sprays are located at intervals of 16 3/4 inches along a 1 1/4 inch water pipe. The pipe, when in use, is mounted on tripods approximately 5 1/2 feet above the ground surface and pivoted in such a manner as to allow rocking action, thus permitting a uniform coverage of the plot by the sprays. Water is supplied from a 500-gallon tank rigidly fastened to the bed of a 1 1/2 ton truck. A double action plunger pump forces the water into a 20-gallon pressure tank from which it flows through a "drop recording" water meter into the spray pipe. The intensity of application is determined by use of a gauge in the pressure tank and the amount applied is recorded by the meter. Steel baffle plates five and six feet long and nine inches wide are driven into the ground to enclose the plot on the sides and upper end. The lower end of the plot remains open thereby permitting runoff water to enter the catchment trough, the top of which is level with the ground surface. A drain valve in the bottom of the catchment supplies a means of measuring runoff into graduated buckets. Wind movement against the fine spray would tend to give uneven application of water to the surface of the plot. A set of canvas curtains adequate to completely enclose the sides of the plot were provided. By this means it is possible to operate the equipment during windy weather.

2. Methods of Procedure.

Rainfall Pattern Method

The spray of water is applied to the plot in intensities which correspond to a high intensity rainfall pattern, the nature of which is common to the 10-year rainfall frequency for the region in which tests are being conducted. Prior to making the study, a graph is prepared which indicated the intensity and amount of water to be applied for each five-minute period of time. As an example, assume that a rain starts with an intensity of 1/2 inch per hour and rapidly increases to an intensity of three inches per hour during the first ten minutes of fall. After which it decreases gradually to a rate of one inch per hour over a period of 15 minutes following which it again increases to 2 1/2 inches per hour and then again drops in intensity to 1 1/2 inches per hour after a lapse of 20 minutes more. It may then dwindle down to 1/2 inch per hour over a further period of 10 minutes and cease altogether within a quarter of an hour. A rain of this kind is not uncommon in the vicinity of Colorado Springs, particularly during the warm days of mid-summer.

The duration of the tests have varied from one hour to one hour and 30 minutes. Once the test starts, great care is exercised in the effort to follow the rain pattern in every detail. Meter readings are taken each five minutes to determine the amount of water applied. The time elapsing between the start of the test and the beginning of runoff is recorded and the amount of runoff is recorded at each interval until the rain stops and thereafter until all water ceases to flow from the surface of the plot.

The storm pattern type of test has given valuable indications of runoff in localities where accurate weather records are available. This method of testing should, however, be based upon a thorough knowledge of infiltration capacity. For this reason the stabilized infiltration test offers a better guide to the initial study of runoff and infiltration.

Stabilized Infiltration Method

Stabilized infiltration studies differ from rainfall pattern tests in that each rate or intensity of application remains the same until the infiltration and runoff become con-

stant. Each run involves the use of from 4 to 6 different rates of application on the same plot. For example, assuming that a test is started at the high rate of application of 6 inches per hour, the amount of water applied and the runoff is recorded at intervals of 2 minutes. Assuming that after the fifth 2 minute period the runoff becomes constant and remains so until the 10th period when the rate of application is decreased to 4 inches per hour and the process repeated. This procedure is continued until the entire scale of possible rainfall intensities have been covered or until a rate of application becomes so low that runoff ceases entirely. The data secured is plotted on graph sheets in the manner illustrated in Graph Number 2. For a complete record of the infiltration capacity of the soil under test it is necessary to repeat the runs on the same plot after an interval of 24 or 36 hours.

A record is made at the beginning of the test of the vegetative cover, temperature of soil, water and atmosphere, land use, slope, soil type, organic matter content of topsoil and the moisture condition of the soil.

All stabilized infiltration studies which have been made to date are based upon rainfall intensities known to occur on that particular area during a 10 year frequency. In some localities, particularly on porous soils, this practice will not offer sufficient data to give a complete graphic picture of the time that infiltration starts nor of the infiltration capacity of the soil under test. However, higher rates per hour may be used on porous soil types in order to reach the infiltration capacity more quickly.

3. Suggested Improvements in Apparatus and Technique. (These suggestions have been accumulated by correspondence, personal observation, and notations in the field, and from existing publications.)

   (1) It is suggested that the nozzles be changed to utilize the commercial form known as a "cat fish" nozzle, and that these be screwed into the delivery pipe in two rows and alternately spaced so as to give a wide coverage of varying size drops, rather than a thin line of uniform drops.

   (2) A small gas engine should be installed on the truck to operate the pressure regulator and the rocker arm of the sprinkler pipe, thus giving more uniform pressure and application of water.

(3) The runoff water should be diverted by baffles and a suitable pan through a small flume into a measuring can equipped with float and stage recorder. Troughs should be placed along the sides of the baffles to catch water which is thrown over the side of the plot and against the baffles.

(4) The supports for the spray apparatus should consist of a frame along the sides of the plot to eliminate trampling of the plot when setting up the tripods now used.

(5) The water meter should record in gallons and the pressure meter should be sensitive enough to record variations as close as one-half pound pressure.

(6) The supports for the delivery pipe should be adjustable so as to change the elevation of the pipe, equalizing the pressure at the two ends.

(7) Funnel type screens should be placed in the tanks and pipes to prevent clogging of the sprays by accumulated trash.

(8) The ratio of length to width of plot should be increased to emphasize slope effects.

(9) There should be a closer cooperation of effort in timing the readings of pressure, application and runoff.

(10) Careful effort should be used in the selection of testing sites to see that these are representative of the soil, slope, erosion and cover conditions to be examined. A sufficient number of tests should be run to give a reasonably accurate picture of the runoff and infiltration characteristics of each important variation in the above four factors.

(11) Since rainfall intensity data are so meager, it would be better to use the stabilized infiltration method as suggested by the Colorado Springs report, rather than the rainfall pattern method. It appears that the infiltration rate under various intensities of application is of more importance than the percent of runoff, since it is a fundamental property of the conditions of the ground and may be expected to be constant within a given range of rainfall conditions.

(12) To give a complete picture of the influence of structures on water retention and distribution, it is advisable that the infiltration rate be determined simultaneously with the rainmaker test in order to give a picture of the ef-

fect of ponding the runoff water on its subsequent distribution in the soil profile and probable loss by evaporation.

(13) Before wide application is made of the rainmaker or similar equipment for testing runoff and infiltration properties, it should be standardized against the recognized methods of determining runoff on watershed areas. It should be possible to do this when the hydrological watershed studies are initiated.

4. Discussion of Results and Applications.

A rather thorough discussion of the results of the Colorado Springs rainmaker investigations is given in their report of July, 1937. Undoubtedly there are a number of factors which tend to make the data obtained difficult of interpretation; however, the usefulness of such data in developing a program of moisture conservation and utilization warrants the further development of technique and apparatus, and extensive use of this method on areas where runoff and infiltration characteristics are unknown.

There is a great need for information regarding the local variations in rainfall intensity and frequency, both with regard to seasonal and annual distribution. The results of the work at Colorado Springs has furnished engineers on those projects and camps with excellent background for the design and construction of water retention and diversion structures. Runoff tests which were made on the Clayton and Cheyenne Wells Projects indicate that wind erosion has increased greatly the runoff from these lands. Bare fields from which all of the topsoil had been removed, exposing a clay subsoil of low permeability, showed two to three times the runoff characteristics of the original soil.

The runoff on range lands at Cheyenne Wells has increased tremendously due to the accumulation of a fine silt from settling dust storms on the ranges. This same effect is extensive over the High Plains territory. The runoff and infiltration studies have served to point out the steps necessary to overcome these runoff problems, and have aided greatly in the development of a moisture conservation program. Due to the extreme variation in local surface conditions affecting runoff, interpretation of results obtained from the rainmaker or other runoff testing apparatus must be made with full cognizance of these factors. The data must be considered as giving relative or comparative rather than absolute values.

B. Study of Infiltration and Transmission Capacities.

(The apparatus for infiltration studies was developed at the Regional Office independent of the runoff studies which were made at Colorado Springs. The combination of these two systems is highly desirable.)

1. Description of Apparatus.

a. Variable Head Type.

The infiltration apparatus shown in accompanying charts is designed to measure the rate of intake of water delivered into a ring enclosing a definite area of soil. The apparatus consists of a heavy brass cylinder with a float gauge graduated to read in 10ths of inches of water as delivered in the soil cylinder, and is equipped with a hose and spray for uniform coverage of the soil surface and for control of the rate of delivery. This is mounted on a suitable stand which can be adjusted to compensate for changes in slope, and is set directly over a heavy brass cylinder 6 inches in height and 10 inches in diameter. The latter was driven, with as little disturbance of the soil as possible, by forcing or by tapping to a depth of about one inch into the soil so as to lessen water losses by lateral movement. Temperature of soil and water, humidity of the atmosphere, surface condition of the soil, type of vegetative cover, and other related factors, were recorded for each test. Water was delivered into the soil ring at approximately the rate at which it was absorbed, maintaining a more or less uniform height of water in the ring to prevent errors due to hydrostatics. The water was maintained at approximately 1/4 inch depth in the ring. The float gauge was read at one-minute intervals; however, the data shown on the tables and graphs were summarized for five-minute intervals. Amounts ranging from two to four inches of water were applied in each test.

b. Constant Head Type.

The apparatus designed to give constant head transmission capacities is shown in the accompanying diagram. Since the designing of the apparatus, it has been found necessary to enlarge the soil rings, making the inner ring 12 inches and the outside ring 18 inches inside diameter; otherwise the apparatus is as shown in the prints.

2. Methods of Procedure.

a. Sprinkler Method.

After considerable study regarding the use of rings, it was decided that an 18 inch ring driven approximately 6 inches into the ground gave more consistent results with infiltration studies than rings of smaller diameter, and that rings of larger diameter apparently did not increase greatly the efficiency of the tests.

Water was applied from an ordinary sprinkler attached to the brass cylinder by means of a hose, and the rate of application was controlled to keep the surface of the ground covered with a thin film of water not to exceed a depth of 1/4 inch. By means of a float gauge the amount of water applied was recorded in surface inches and fractions of inches for uniform time intervals ranging from 3 to 5 minutes. Temperature of soil and water, humidity of atmosphere, surface conditions of the soil, type of vegetative cover and other related factors were recorded for each test. The amount of water applied ranged from 2 to 10 inches, depending upon the texture of the soil and the type of study being made.

b. Variable Head Method.

In this method it was decided to do away with the sprinkler system which required two men to operate a single apparatus, and to apply water in uniform increments of one inch to several rings set at approximately the same depth and located at random over the testing site. It was found that 18-inch rings set to a depth of 6 inches were most satisfactory for this purpose. The amount of water to be applied was measured in separate containers and added to each ring by simply pouring the water over one's hand held very close to the surface of the ground inside the ring. The time was recorded for this amount of water to completely enter the ground, and application of another increment was immediately made.

Such a procedure was continued until 7 or 8 inches of water had been added. In order to lessen the effect of lateral movement around the edges of the soil ring, outer rings of 18 inches were provided in preliminary tests with 12-inch inside rings driven to the same depth and receiving the same depth of water at each addition. It was found that this was no more satisfactory than the use of the single 18-inch ring alone, and was abandoned in favor of the use of several 18-inch rings operated simultaneously.

c. Constant Head Method

In this method the constant head apparatus, as shown in the accompanying diagram, was set to maintain a constant depth of one inch, using a 12-inch inside ring and an 18-inch outside ring. The depth in the outside ring was maintained at approximately the same height as in the inner ring by close adjustment of the valve. Readings were taken every five minutes until 5 inches to 10 inches of water had penetrated the ground. The depth of penetration, temperature, surface conditions, and other related factors were recorded as in the sprinkler and variable head tests.

3. Suggested Improvements in Apparatus and Technique.

The difficulty in simulating natural conditions affecting infiltration and transmission of water through the soil profile makes the choice of apparatus and procedure rather difficult. In the case of the sprinkler method, it was difficult to obtain a type of sprinkler which would give a spray of drops approaching ordinary rainfall drops in size, and at the same time maintain an application rate approximately the rate of intake. In most cases where the rate of intake was very slow, the water merely dripped from one corner of the spray. Improvement in this method might be made by -

(1) Using a pressure tank and applying the water through a fine spray into a large ring, say 24 inches in diameter, regulating the application to maintain a thin film of water over the surface of the ground;

(2) Driving the soil ring to a depth of approximately 6 inches to eliminate as far as possible lateral losses;

(3) Providing an external glass gauge for measuring water delivered;

(4) Constructing the apparatus in such a manner that it can be readily moved and set up so as to allow a large number of determinations.

In the variable head method, the most important point seems to be in selecting the locations of the rings so as to give a more or less representative picture of the area being

tested. This method has the advantage over others used, in that one operator may make several tests simultaneously. Due to the variation in local factors affecting infiltration, such as irregularities in surface conditions, ponding on surface retention areas, and variations in type of cover and immediate surface conditions such as crusting, this method apparently offers the simplest and perhaps most useful means of determining intake rate. It serves to give a picture of how the intake of water may be affected by local obstructions such as mechanical retention devices where a variable head of water would be the prevailing condition.

The constant head apparatus has as its advantage the elimination of the human error in adjusting the rates with which water is delivered into the soil cylinder and variations in depth affecting the rate of intake. It does not, however, represent the rate of intake which one might expect under natural conditions, as it measures the relative transmission capacities under a given head. The apparatus shown in the design is satisfactory for this type of test, with the exception that improvements in the float valve could be made and a float constructed for regulation of the water in the outer ring.

4. Discussion of Results and Application.

Considerable field work has been done studying these different methods of obtaining field infiltration and transmission capacities. In the variable head method, 10", 12", 15", 18" and 24" rings were tried in combination and singly. It was found that the single 10-inch and 12-inch rings gave much higher infiltration rates than the 18-inch and 24-inch rings, apparently due to the greater error of lateral movement under the edge of the ring. The 18-inch and 24-inch rings were fairly close together in their results, with the 15-inch ring falling between the two smaller and two larger rings in rate of infiltration. Since the 18-inch ring gave results comparable with the 24-inch, it was selected for field use as it could be handled more readily. Tests made with combinations of rings gave results which were no better than the single rings of larger size.

In comparing the different methods of application, it was found that the constant method apparatus gave the highest rate. The variable head method was somewhat lower but still faster than the spray method. If a satisfactory apparatus

for conducting simultaneously several spray tests in the field can be constructed, it appears that this would be the more satisfactory procedure.

Infiltration tests were made on the projects at Guymon, Oklahoma, Clayton, New Mexico, Clovis, New Mexico, and Cheyenne Wells, Colorado. In all of these the object was to secure a comparative value of the infiltration capacities of principal soils. At Clovis, New Mexico, a series of tests were run on soils ranging in texture from a heavy loam to dune sand. A graph showing the results of these tests is enclosed. These data have been of considerable value to the engineers in their work of designing and constructing moisture retaining structures such as terraces and contour furrows. Infiltration studies on the other projects mentioned were carried out on only a few of the soils, and more work needs to be done before the data are ready for use by the engineers.

At Clayton, New Mexico, and at Cheyenne Wells, Colorado, infiltration tests were run concurrently with "rainmaker" tests. Apparently the ring methods for determining infiltration capacities will always give higher results than those obtained by use of the "rainmaker". For comparison, a graph of a single run is enclosed. The retention of the water in place, creation of a slight head, a loosening of the ground around the edges of the ring when it is driven in, lateral loss of water under the lower edge of the ring, and elimination of the runoff due to slope, all have an effect on increasing the infiltration rate by the ring test over that of the runoff method.

Despite the lack of standardization of apparatus and methods, the use of some method for determining relative infiltration capacities of soils on project areas is highly desirable from the standpoint of furnishing valuable information needed in the design, construction and spacing of mechanical water retention structures. It appears that any method which can be handled well in the field and which will give consistent results on a uniform soil type may be used satisfactorily for determining comparative infiltration rates.

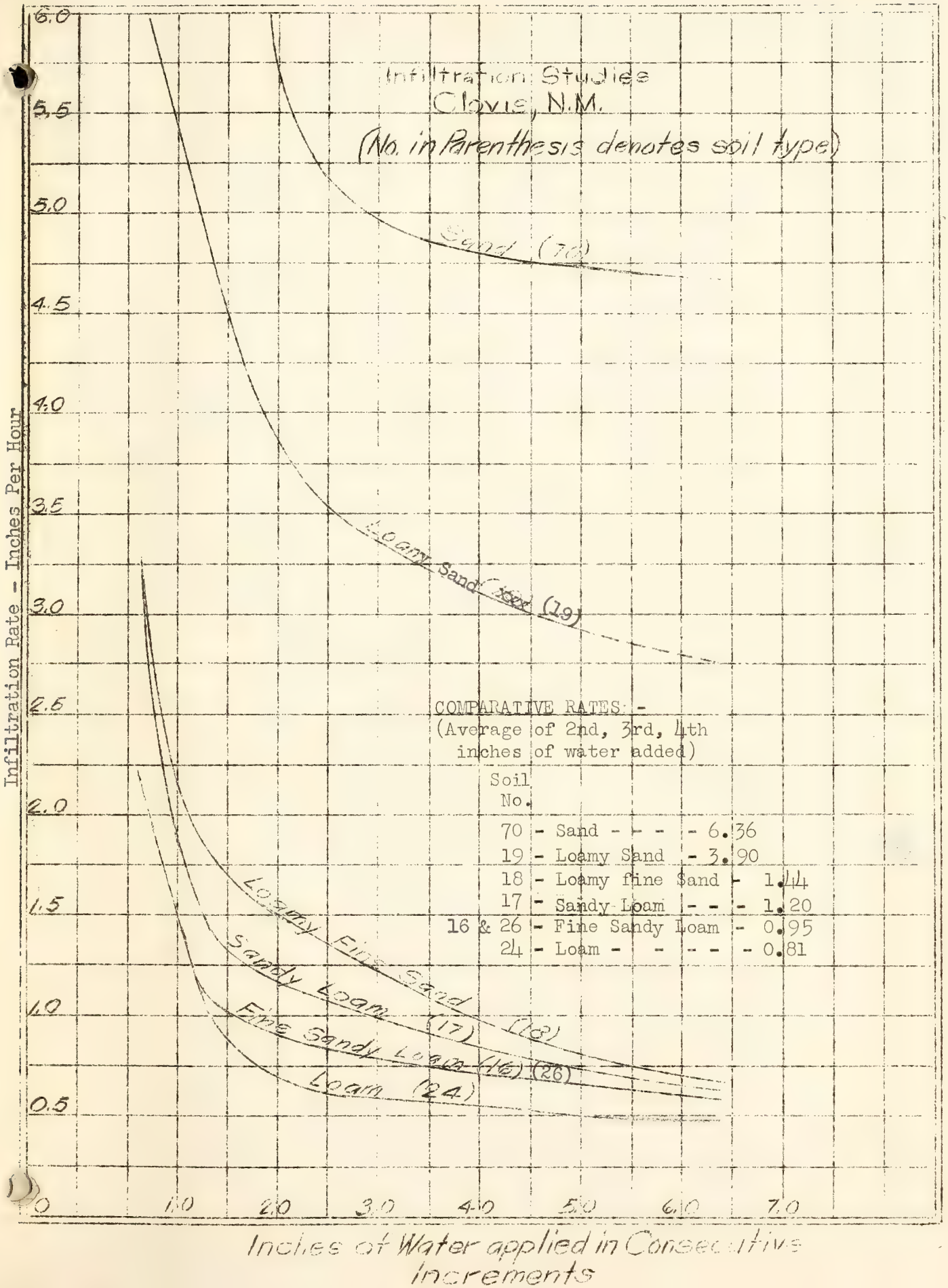
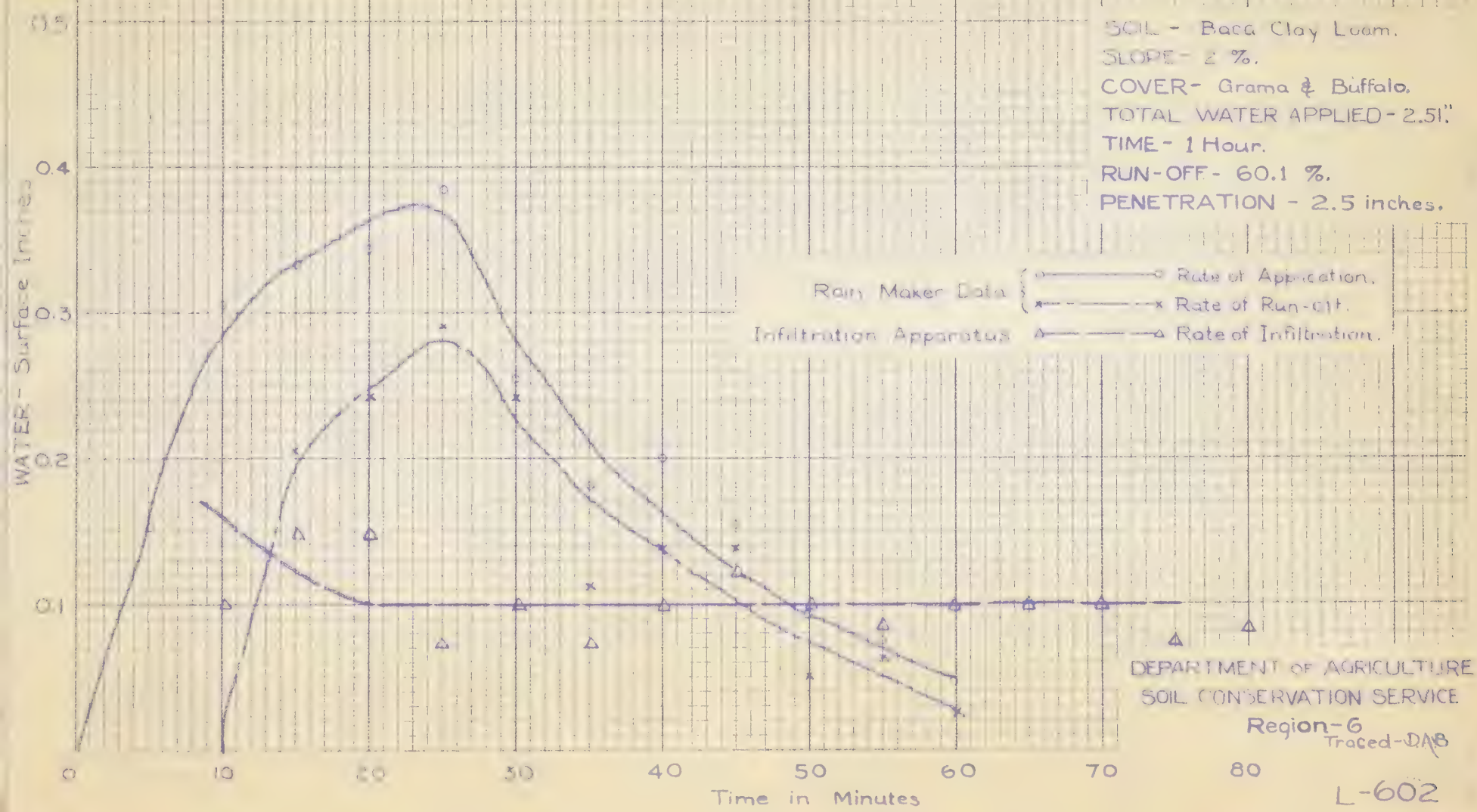

Infiltration Studies
Clovis, N.M.
(No. in Parenthesis denotes soil type)
Sand (70)
Loamy Sand (19)
Loamy Fine Sand (18)
Sandy Loam (17)
Fine Sandy Loam (16) (26)
Loam (24)
COMPARATIVE RATES -
(Average of 2nd, 3rd, 4th inches of water added)
Soil No.
70 - Sand - - - - 6.36
19 - Loamy Sand - 3.90
18 - Loamy fine Sand - 1.44
17 - Sandy Loam - - - 1.20
16 & 26 - Fine Sandy Loam - 0.95
24 - Loam - - - - - 0.81
Infiltration Rate - Inches Per Hour
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
Inches of Water applied in Consecutive Increments

Fig. - 10

COMPARISON OF "RAIN MAKER" TEST No. 298 WITH INFILTRATION TEST

S.C.S. PROJECT NM-4



DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Region-6
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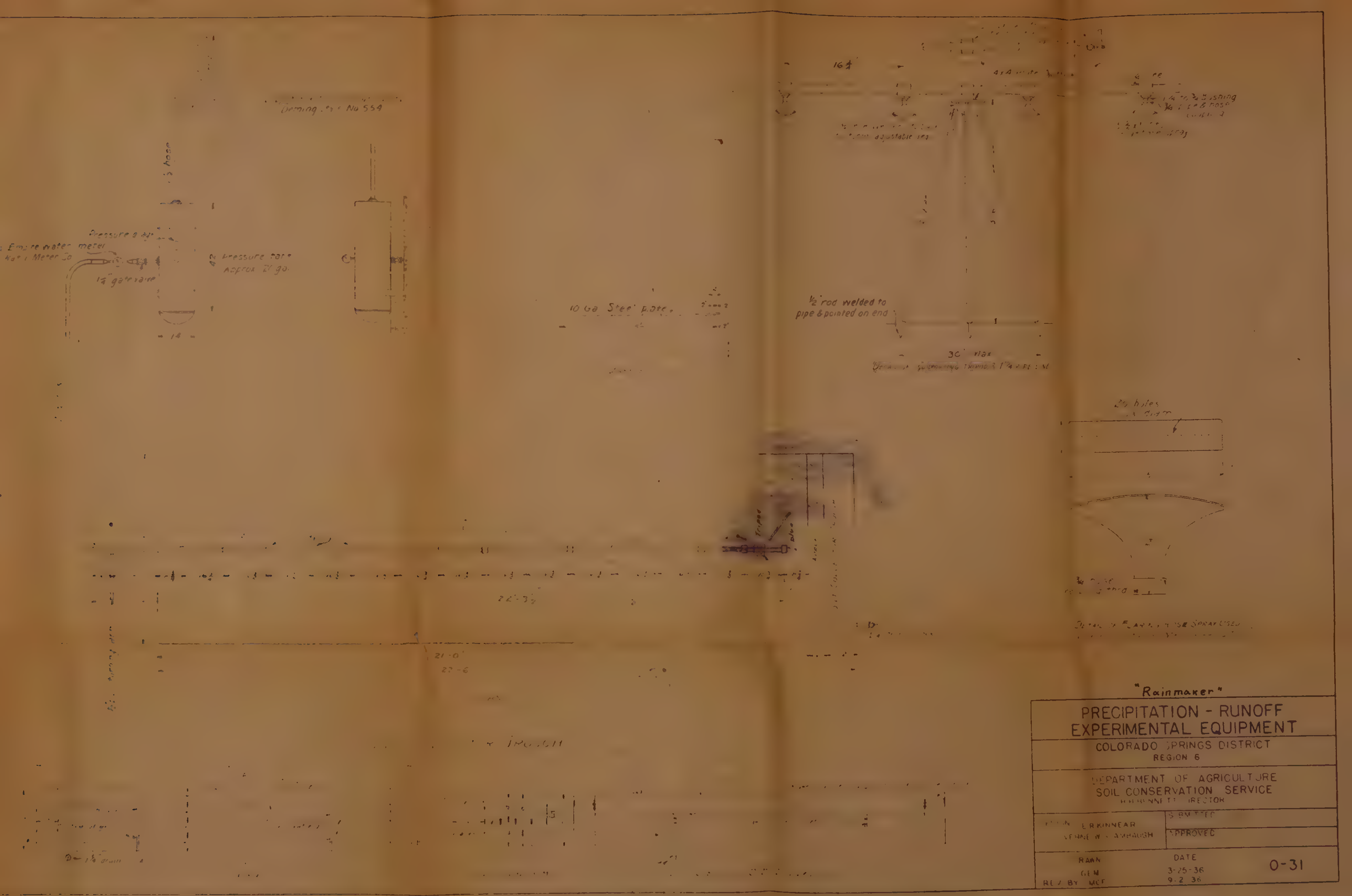


"Rainmaker"

PRECIPITATION - RUNOFF
EXPERIMENTAL EQUIPMENT

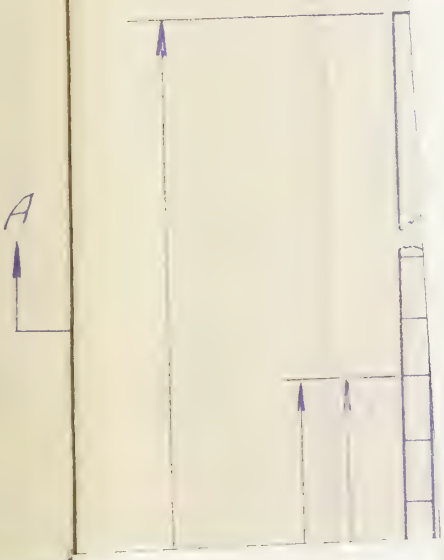
COLORADO SPRINGS DISTRICT
REGION 6

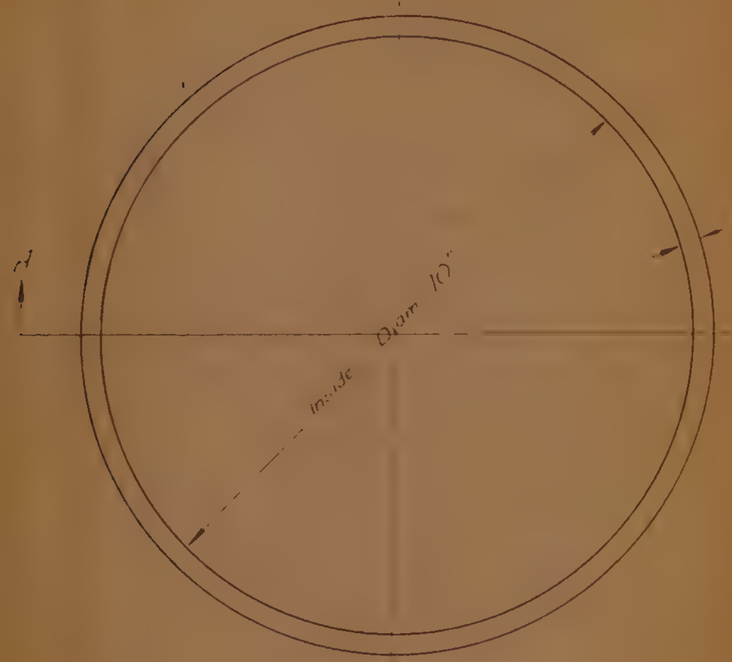
DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
H. H. BENNETT, DIRECTOR

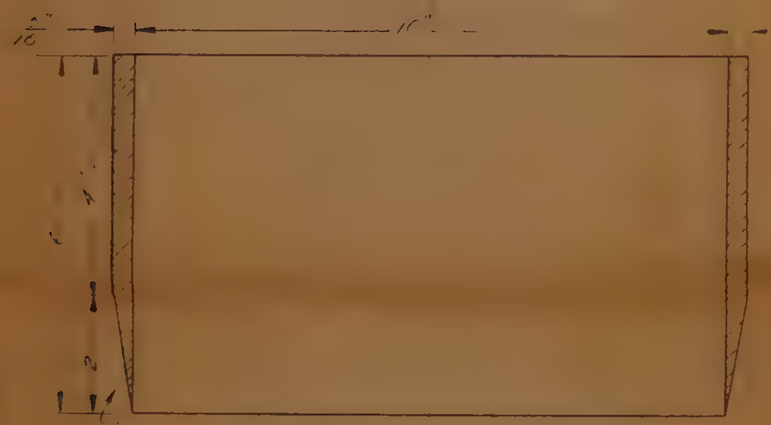
DESIGN E. R. KINNEAR STEPHEN W. ARMBURGH	SUBMITTED APPROVED
DRAWN GEM REV. BY MCF	DATE 3-25-36 9-2-36

0-31

s Cap. 16 gauge
3/8 Hole in Cent

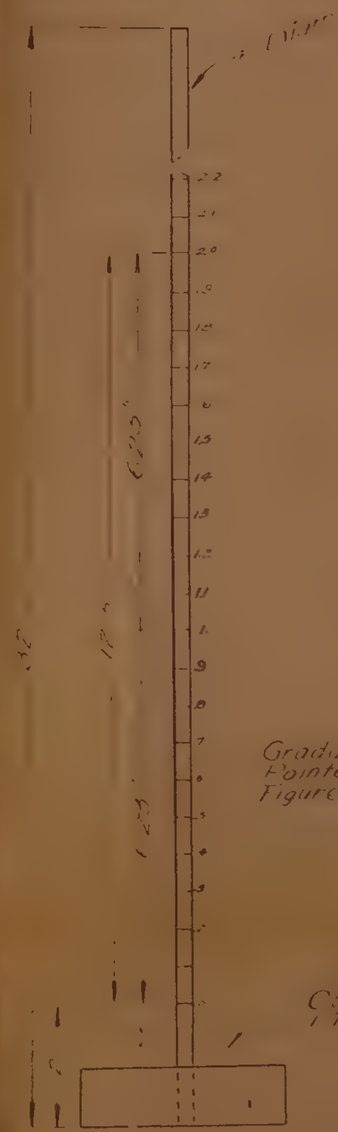






Section AA

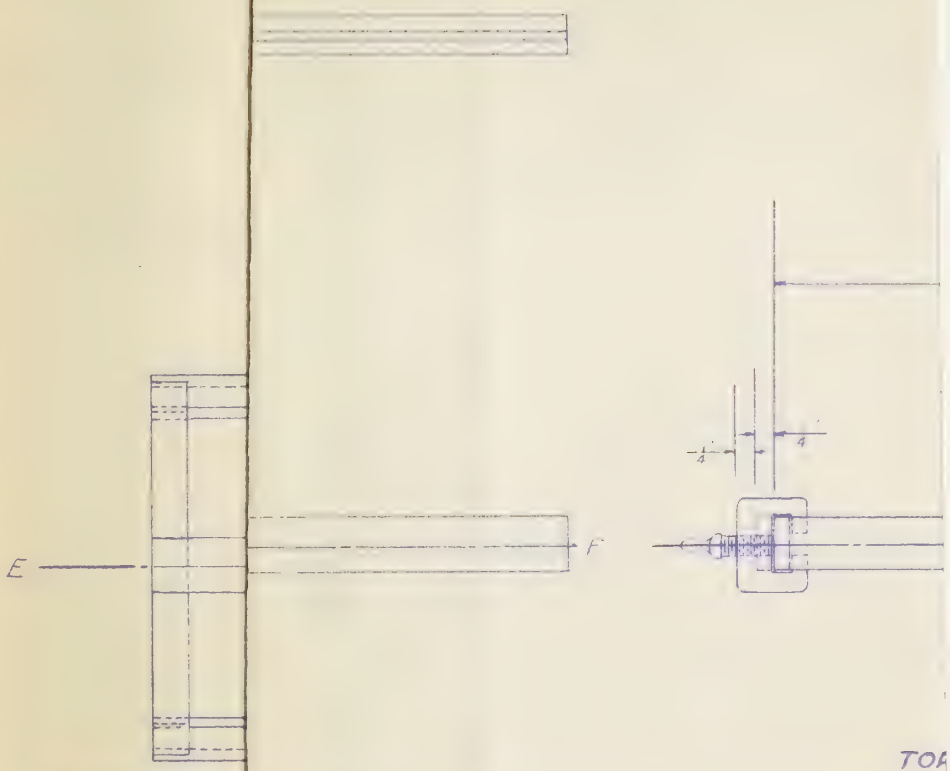
Brass Cylinder Open at Top and Bottom



"Variable Head or Sprinkler Type"

TEST CYLINDER
FOR WATER ABSORPTION
DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
H H BENNETT Chief

References	Scale
Submitted By G.E.	Approved By B.L.F.
Designed By Carpenter	Revised By
Drawn By A. / Traced By R.L.	Date / No C-103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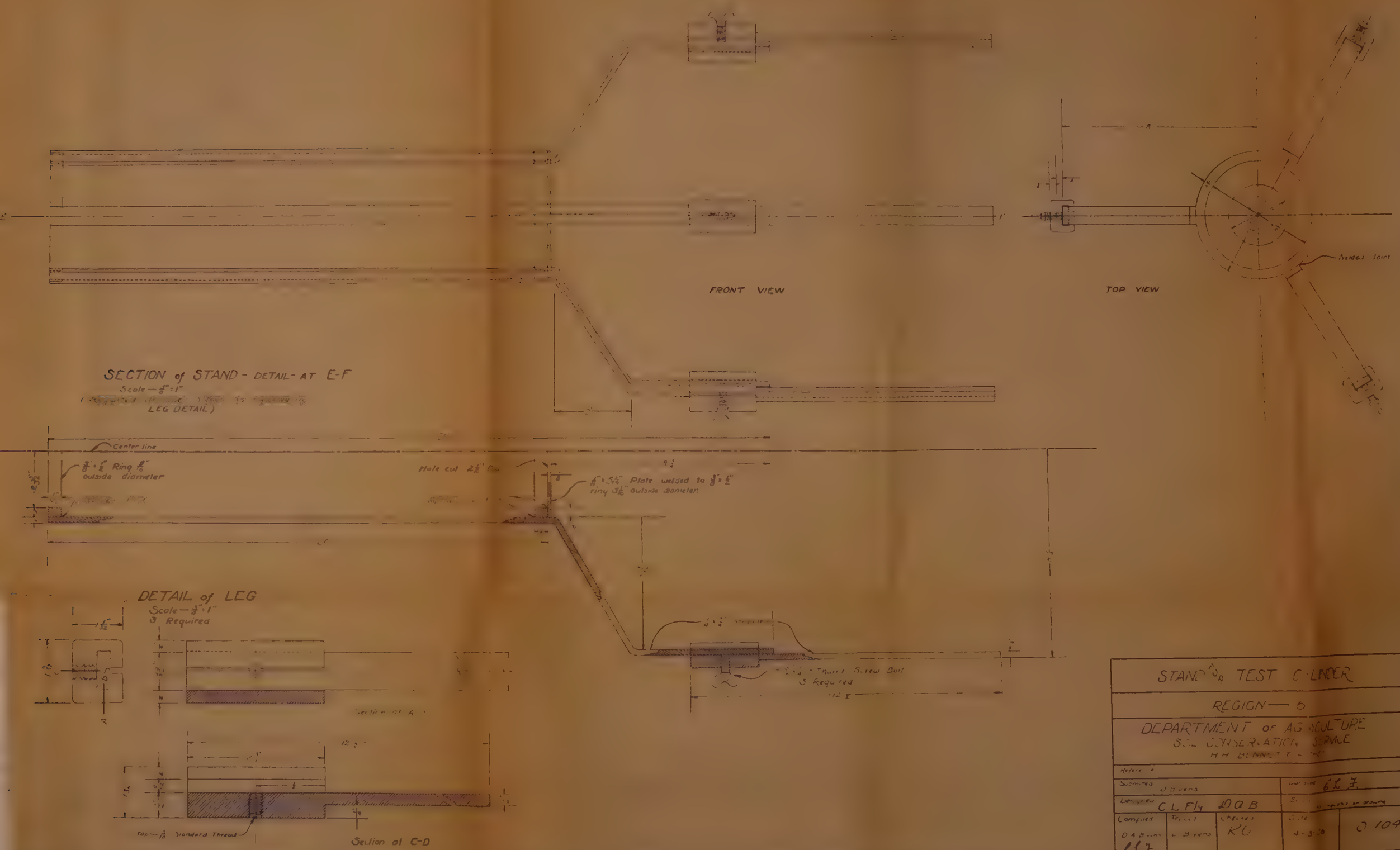
4
TOP

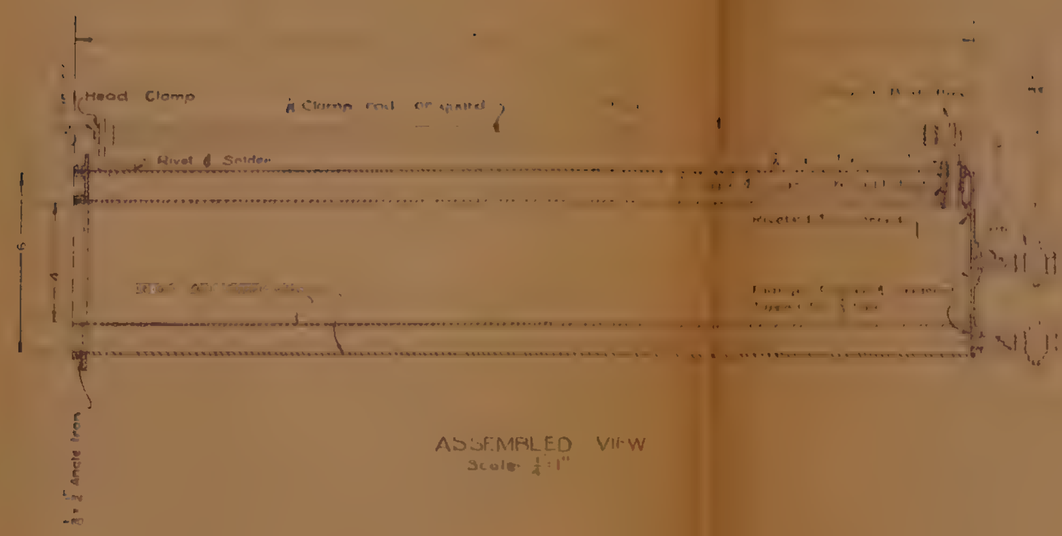
STAND FOR TEST CYLINDER



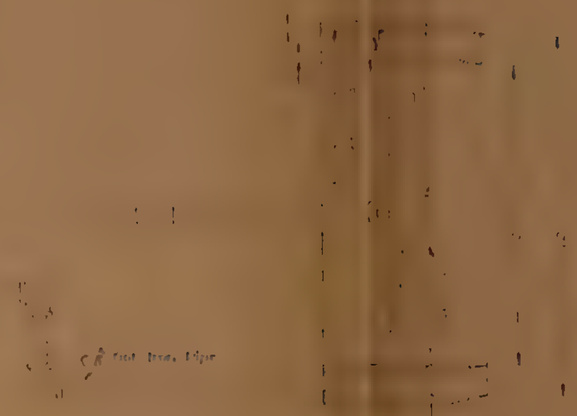
STAND FOR TEST CYLINDER			
REGION — 6			
DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE H. H. BENNETT — CHIEF			
Reference			
Submitted D. B. Evans			Date 6 L 7
Designed C. L. Fly D. A. B.			Scale
Completed D. A. Brown 6 L 7	Traced C. B. Evans	Checked K. G.	Date 4-3-40	0 109

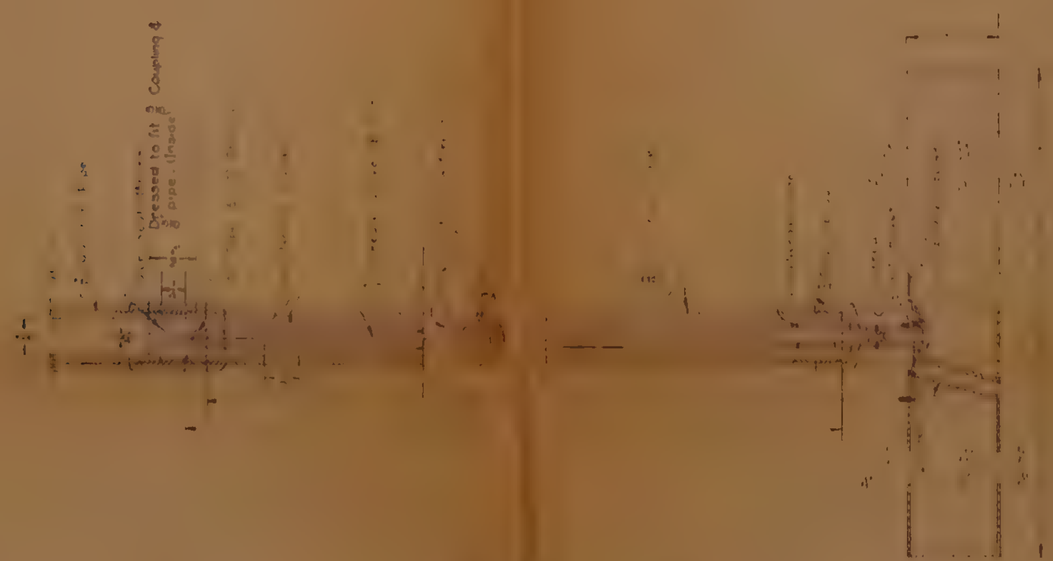
INFILTRATION APPARATUS

"Constant Head Type"

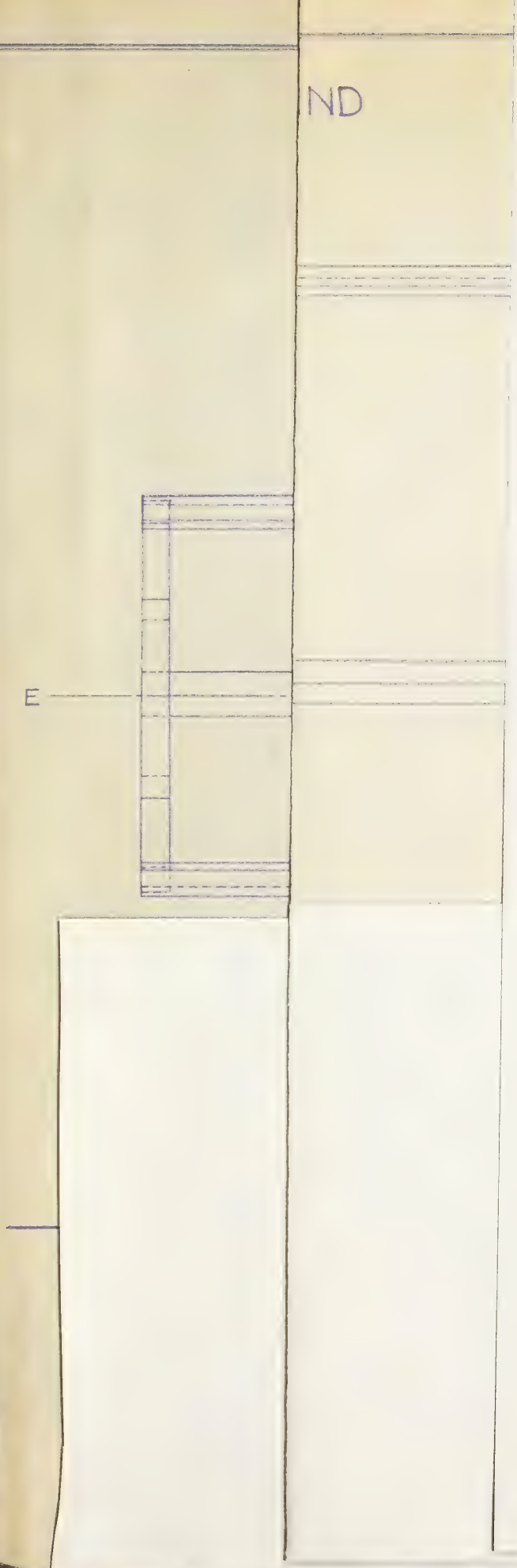


ASSEMBLED VIEW
Scale: $\frac{1}{4}$:1"





Side View — FLOAT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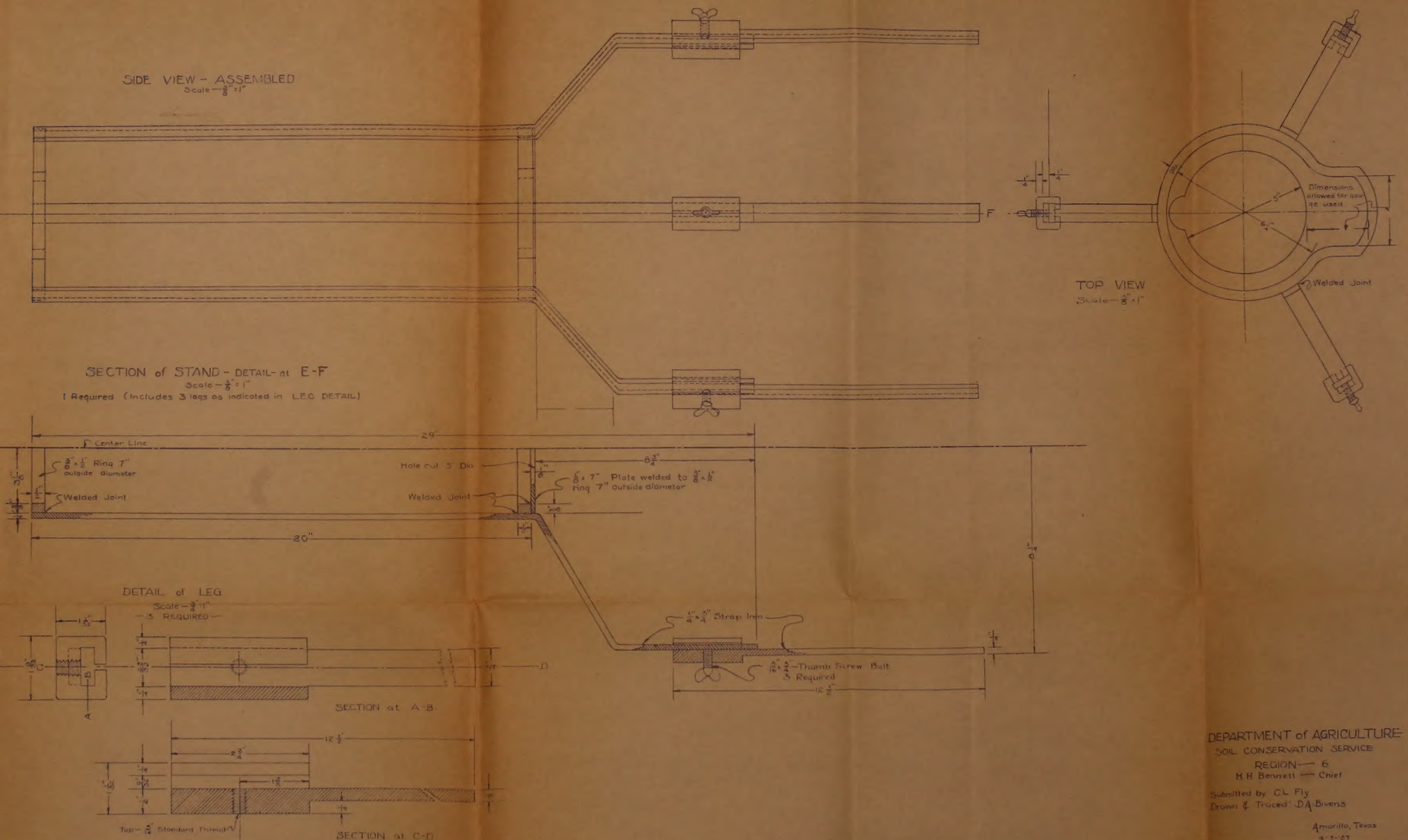
INFILTRATION APPARATUS – STAND



DEPARTMENT of AGRICULTURE
SOIL CONSERVATION SERVICE
REGION — 6
H. H. Bennett — Chief

Submitted by C.L. Fly
Drawn & Traced D.A. Bivens

Amarillo, Texas
4-7-37

O-443